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Economic Intelligence Report

PRODUCTION OF ELECTRONIC COMPUTERS IN THE USSR 1958–65

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CENTRAL INTELLIGENCE AGENCY

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FOREWORD

This report assesses the growth of production of electronic digital and analog computers in the USSR primarily during the current Seven Year Plan (1959-65). An estimate of the annual value of production of each category is provided, together with estimates of the numbers of units of specific types produced. These data are compared with available US information.

The purpose of this report is to provide an analysis of the economic significance of production of electronic computers in the USSR, and the report, therefore, does not attempt an extensive coverage of the detailed technical characteristics of Soviet machines or of their performance in various applications.

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PRODUCTION OF ELECTRONIC COMPUTERS IN THE USSR*
1958-65

Summary and Conclusions

Intensive work in research on and development of electronic computers** has been carried out in the USSR since the end of World War II. Initially, emphasis was placed most heavily on analog computers, and since 1950 a growing economic capability in this field has been evident. A wide range of types of analog computers has been produced for routine use in schools, scientific laboratories, and industry and in military applications. Although the majority of Soviet analog computers do not meet the levels of performance of the better US devices, they are clearly adequate for a wide variety of important applications. In contrast to the relatively strong position of the USSR in the area of analog computers, Soviet production of digital computers until recently has exhibited a much slower rate of growth, and production technology in the digital computer field has been markedly inferior to US practice. Beginning in about 1956, however, the economic effort devoted to production of digital electronic computers has been intensified, and production of digital computers at the present time is showing signs of vigorous growth.

In 1959 the estimated value of Soviet production of electronic computers was approximately 490 million rubles ($82 million),*** representing approximately 1.6 percent of the total value of electronic equipment produced in the USSR for that year. In the US the value of

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* The estimates and conclusions in this report represent the best judgment of this Office as of 1 January 1961.

** The term electronic computer refers to a broad category of equipment for manipulating information and performing calculations by electronic, or a combination of electronic and electromechanical, means. The terms automation equipment or electronic data processing equipment also are used in reference to such equipment. The term electronic computers refers primarily to electronic analog and digital computers and their associated input, output, and information storage devices. For further details, see I, C, p. 6, below.

*** Ruble values in this report are given in 1955 rubles and may be converted to US dollars at a rate of 6 rubles to US $1. This rate does not necessarily reflect the value of rubles in terms of dollars. For methodology, see Appendix C.

production of computers in 1959 reached approximately $1 billion, or about 10 percent of the value of electronic equipment produced that year. In 1965 the USSR will produce electronic computers valued at approximately 1.8 billion rubles ($300 million), more than 3.5 times the 1959 value. Although the rate of growth indicated by the current plan is substantial, it is not markedly different from that experienced in the US and other Western nations and is insufficient to enable the USSR to make a significant relative gain on the US by 1965.

The planned growth in Soviet production of computers is based on an ambitious program for expansion of the production base. Up to the present time, almost 90 percent of the total production of computers has been concentrated in two major plants. The current plan envisions a more widely dispersed industry with 5 computer plants currently under construction and 17 additional plants scheduled to begin production by 1965. Difficulties in planning and production and shortages in specialized components have been cited extensively in the Soviet press in the last few years, reflecting some of the problems that are hampering the growth of this sector of electronic equipment. The planned capital expansion program will continue to create difficulties in the coordination of production engineering with the research and design institutes on the one hand and the electronic components industry on the other. The increased production facilities, however, will provide steady increments to the total Soviet capability to produce computers during the next few years.

The over-all growth of Soviet production of computers and the differential rates of growth between analog and digital computers during 1958-65 reflect both an expanding industry and a maturing technological pattern wherein digital computational methods will replace analog techniques in a number of important applications. Production of electronic computers in the USSR in 1958 was about equally divided between analog and digital machines. Under the current Seven Year Plan (1959-65), which places heavier emphasis on production of digital computers, the annual value of production of digital computers by 1965 will be about 3.5 times the value of analog computers produced that year.

The most significant recent developments in digital computers have included the introduction into serial production* of three new types of large digital computers, the BESM-II, the Ural-II, and the M-20. These models represent a degree of improvement over earlier production models that is sufficiently impressive to identify them as a new generation of Soviet digital computers. The latter two models probably will

* The term serial production refers to production of five or more units of a specific type.

be the principal digital machines to be produced serially at least through 1961. By 1962, production of a completely solid state machine may begin. This change will bring with it additional improvements in machine organization, input-output devices, and memory capabilities that will further enhance the over-all capabilities of the USSR in applications of digital computers.

As a result of the slow rate of growth that has characterized production in the past, the USSR has been unable to utilize digital computers to the same extent as the US for other than high-priority efforts in scientific research and military applications. Because of the apparently strict apportionment of computer time to projects of highest priority, past and present shortages of digital computers probably have not seriously hampered critical research efforts or priority military projects.

In spite of widely publicized plans for extending the use of digital computers in industry, nonmilitary uses are still largely in the planning or testing phase. Experimental applications are underway in the field of automation of the chemical, oil, steel, and machine tool industries; in economic planning and accounting; in automatic language translation; in weather forecasting; and in medical diagnosis. The use of digital computers for handling business data and for industrial controls will remain small compared with military and scientific uses and will continue to lag behind the US through 1965. There probably will be a noticeable increase within the next 2 years in the use of computers for regional and national economic planning and other government statistical computations.

I. Introduction

A. Types of Computers

Electronic computers are of two basic types: analog or digital. Analog computers operate with data that are continuously variable, such as voltages, temperatures, pressures, and flows. Analog computers usually are smaller, simpler, and less expensive than digital machines. Mathematical computations in analog computers are simultaneous, so that the speed of computations is unaffected by the number of variables. Analog computers are often used in the simulation of complex theoretical problems such as occur in studies of aerodynamics or in control systems such as those used for missile and gun controls and in industrial process controls. More than 90 percent of all analog computing devices produced in the US in 1959 were purchased by the military.

Digital computers operate with data expressed in discrete numerical values, although in practice digital inputs may be obtained from an analog measurement converted by an analog to digital converter. Digital computers carry out long sequences of operations automatically, referring to memory and stored program for instructions and information. Accuracy is limited only by the number of digits used and the method used for programing. Digital computers are extremely versatile; can be used for problems in business, science, and engineering and for control; and generally are more expensive than the analog computer.

B. Administration of Computer Production in the USSR

Before 1956, production of electronic computers was organized and controlled by the Ministry of Machine and Instrument Building. In 1956 the Ministry of Instrument Building and the Means of Automation was created and assumed control over production of computers until 1957. Following the industrial reorganization of 1957, the two major electronic computer plants, in Moscow and Penza, became subordinate to their local sovnarkhozes (National Economic Councils). The Leningrad Experimental Computer Plant was made directly subordinate to Gosplan. Other experimental plants probably are administered by institutes of the Academy of Sciences, USSR. Long-term technical planning in the fields of electronic computers and industrial automation apparently is accomplished jointly by the State Committees on Radio-Electronics, Scientific Engineering, and Automation and Machine Building. Economic considerations are coordinated through Gosplan, local sovnarkhozes, and individual plants. 1/*

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C. Commodity Coverage

Estimates of the value of production of electronic computers in this report are based primarily on plan data relating to the production of equipment termed by the USSR as "computing and mathematical machines" (schetnyye i matematicheskiye mashiny). In the context of Soviet statements, however, it is clear that in official plan data the value of production of some types of electromechanical office machines, such as calculators and adding machines, also is included. The value series constructed from plan data, therefore, was deflated by the amount of the estimated value of production of these nonelectronic devices.* The product mix between electronic digital and analog computers was estimated by calculating the production index for analog computers from officially announced rates of growth and by applying the value weight for 1958, a base year in which the product mix was known. The resulting value series was subtracted from the value series for both digital and analog machines to obtain the series for production of digital computers. An independent check on the total value series for computers was made by estimating the cumulative value of all computers produced between 1950 and 1958 and by comparing this estimate with the equivalent data derived in the series based on plan announcements. As a further check on these computations, the estimated average labor productivity in the electronics industry as a whole was applied to the estimate of labor force in the plants known to be producing this type of equipment.**

II. Production

A. Estimates of Production

In 1959 the estimated value of Soviet production of electronic computers was approximately $82 million, or 8 percent of the value of US production for that year. Of the total electronic computers produced, digital computers represented about $42 million, and analog computers represented about $40 million. Electronic computers accounted for about 1.6 percent of the total value of production of electronic equipment in the USSR in 1959. In the US the

* It is believed that the value of all general-purpose nonmilitary computers and, except for some military electromechanical analog computers, all military computers produced in the USSR are included in the estimates of this report. Many specialized devices manufactured for a particular control application are not considered to fall into the category of computers and are not covered in this report. For further details, see Appendix C.

** The details of these steps are provided in Appendix C.

share of the total production of electronic equipment represented by electronic computers in that year was approximately 10 percent.* 2/

The estimated trends of growth in the value of production of electronic computers during 1958-65 underscore the increased emphasis that is now being placed on production of digital machines under the Seven Year Plan (see the chart, Figure 2**). Before 1956 the annual value of production of analog computers exceeded that of digital computers. As shown in Table 1*** and in the chart, Figure 3,** by 1958 the total value of production of electronic computers was approximately equally distributed between analog and digital types. The differential rates of growth for the next few years, derived from data on the Seven Year Plan, indicate that by 1965 the annual value of production of digital computers will be about 3.5 times that of analog machines. Whereas the rate of growth for analog computers has been declining and that for digital computers accelerating, the rates of increase for both types have been substantial, reflecting both an expanding industry and a maturing pattern wherein digital techniques will replace analog techniques in a number of important applications. Because each type of computer has some unique capability or weakness in specific applications, Soviet demand for both will continue to grow as the economy expands.

Between 1950 and the end of 1959 the USSR produced approximately 400 digital computers compared with more than 6,000 produced in the US in that period. 3/ Of the US machines, approximately 3,000 are still in use. Of the 400 Soviet units, at least 300 are the small-size Ural-I type, whereas about 400 of the US digital computers still in use are large general-purpose machines, each valued at $1 million or more. The USSR produced between 4,000 and 5,000 general-purpose analog computers during 1950-58, or about the same number of general-purpose machines as were produced in the US in the same period.

Serial production of electronic digital computers did not begin before 1956 in the USSR, although significant developmental work and laboratory scale production had been initiated shortly after World War II. Serial production of analog computers had begun several years earlier than that of digital computers. It is believed that, as

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* For a graphic comparison of the value of electronic computers produced in the USSR and the US for selected years, see the chart, Figure 1, following p. 8. Estimates of the value of production of computers in the USSR for each year of the period 1950-65 may be found in Tables 2 and 3, Appendix C, pp. 44 and 46, respectively, below.

** Following p. 8.

*** Table 1 follows on p. 8.

Table 1

Estimated Value of Production
of Electronic Analog and Digital Computers in the USSR a/
1958-65

	Analog Computers		Digital Computers	
Year	Index (1958 = 100)	Value b/ (Million 1955 Rubles)	Index (1958 = 100)	Value b/ (Million 1955 Rubles)
1958	100	200	100	200
1959	120	240	125	250
1960	140	280	165	330
1961	160	320	220	440
1962	175	350	295	590
1963	185	370	395	790
1964	195	390	530	1,100
1965	200	400	695	1,400

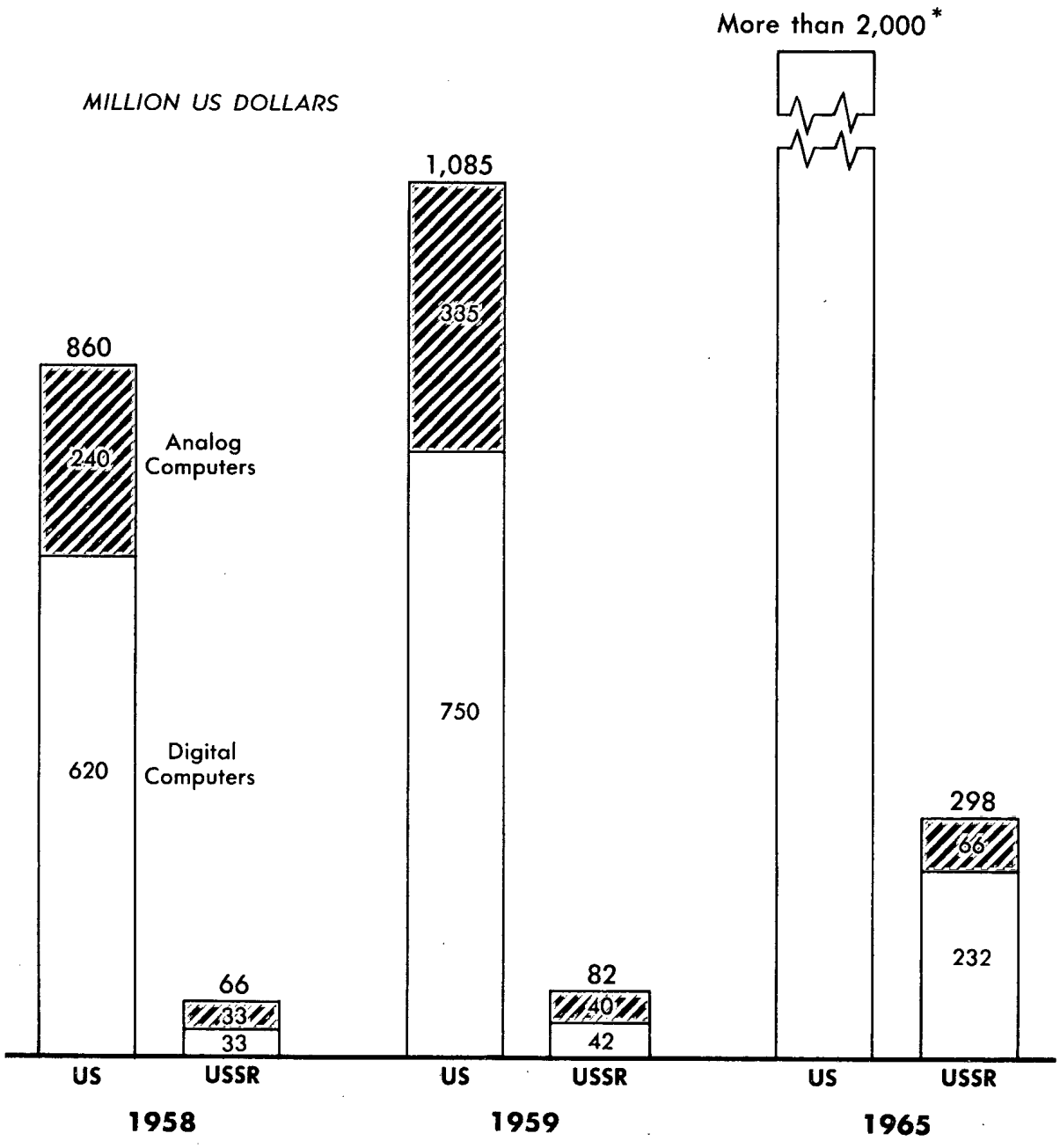
a. After computation, value data were rounded to two significant digits, and indexes were rounded to the nearest five. For sources and methodology, see Appendix C.
b. Although the method of estimating this value series was based on a figure for a base year of 1958, it should be noted that computer pricing for plan purposes probably is still done in terms of 1955 rubles, which may be converted at the rate of 6 rubles to US $1.

of early 1960, 5 or 6 different models of digital computers and 10 to 12 models of analog computers were in serial production. 4/

The planned value of production of analog and digital computers in the USSR in 1965 will be about 4.5 times that of 1958 and more than 3.5 times that of 1959. Although this rate of growth is substantial, it is not markedly greater than that experienced in the US in this area of production, and it is insufficient to enable the USSR to make an important relative gain on the US by 1965. Because very few Soviet machines will be devoted to routine business and statistical purposes, this rate of growth does imply a significant annual increment to Soviet capability in computation for military and scientific purposes.

Figure 1 50X1

USSR AND US
COMPARISON OF THE VALUE OF PRODUCTION OF ELECTRONIC COMPUTERS
1958-59 AND 1965



*Additional data are not available. Conservative market estimates place the figure in excess of $2,000 million for all types of electronic computers. Probably not less than 70-75 percent of the 1965 volume will consist of digital machines.

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Figure 2

USSR: VALUE OF PRODUCTION OF ELECTRONIC COMPUTERS 1958-65

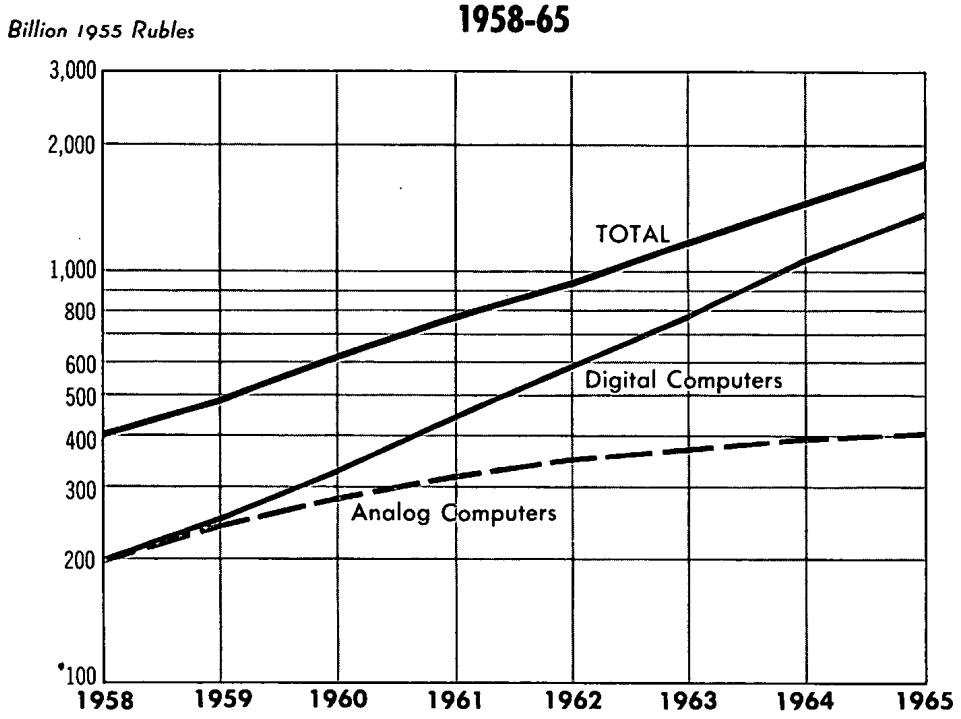
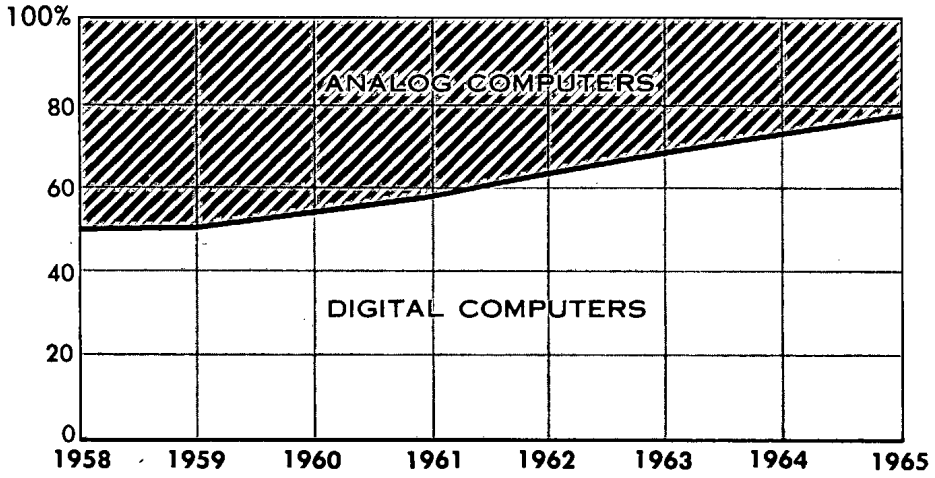


Figure 3

USSR: PERCENTAGE DISTRIBUTION OF THE VALUE OF PRODUCTION OF ELECTRONIC COMPUTERS, 1958-65



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B. Facilities

Soviet electronic computers are built in three types of production facilities: producing plants, institutes, and experimental plants. The basic plants producing electronic computers are under control of Gosplan, USSR, and of sovnarkhozes. 5/ In the USSR, most production of electronic computers is believed to take place at two producing plants: the Moscow and Penza Computer and Analytical Machine Plants, which have a combined labor force of 10,000 employees. In 1958, production of electronic computers at these plants amounted to approximately 348 million rubles ($58 million), or almost 90 percent by value of the total Soviet production of electronic computers.

Under the Seven Year Plan the capacity of production facilities is scheduled to be increased several times. At the end of 1959, announced plans called for 22 computer producing plants to be in operation by the end of 1965. 6/ The 22 plants may include some plants for production of office machines and industrial control equipment as well as of electronic computers. As early as 1957 it was announced that "32 plants for making electronic computers and automatic apparatus are to be erected in the USSR during the next few years." 7/ Five computer plants are presently in various stages of construction. These plants include the Leningrad Experimental Computer Plant, which was under construction and planned to begin production in 1958; the Experimental Plant of the Yerevan Institute of Mathematical Machines and the Vil'nyus Computer Plant, both of which were started in 1957 and as of early 1960 were still under construction; a plant in Estonia, which was under construction in 1958; and the Computer Center of the Ukrainian Academy of Sciences, which was under construction in 1959. Two unconfirmed reports at the end of 1959 indicate the existence of producing plants or facilities for electronic computers in Minsk 8/ and Taganrog. 9/

Slightly more than 10 percent by value of Soviet production of electronic computers in 1958 is estimated to have taken place at facilities other than the Moscow and Penza plants. These facilities include scientific research institutes and experimental plants as well as other minor industrial plants. The share of the total value represented by computers produced in institutes and experimental plants is large because those computers are often one of a kind, are sometimes specialized, and therefore are expensive.

There are about 20 institutes that design and build electronic computers in the USSR. General-purpose electronic computers are developed in institutes of universities and of the Academy of Sciences, whereas special-purpose computers generally are developed by institutes associated with specific industries in which the computers are

to be used or by newly created specialized institutes. For example, the Armenian Research Institute of Computing Machines and Automation is engaged in building electronic computers for the automation of the chemical industry and metallurgical technology. 10/

The prototype of a new design may be built at a producing plant, an institute, or at an experimental plant. Since 1957, construction of several experimental computer plants has begun. These plants are attached to scientific institutes and are intended to relieve the institutes and the production plants in Moscow and Penza of the task of making the experimental models of the computers. Such experimental plants are known to exist in association with scientific institutes in Leningrad, Yerevan, and Kiev. Production of components as well as of computers will take place in the Yerevan and Leningrad experimental plants.

In addition to the added production capacity that will be obtained from new plants, new construction and expansion at the Moscow and Penza plants also is planned. Construction at the Moscow plant since 1956 has already necessitated the expansion of the labor force from 1,500 to 6,000 persons. The planned growth at the Penza plant under the Seven Year Plan, largely new construction, is intended to double the capacity of the plant.

The Moscow Computer and Analytical Machine Plant, with a labor force of 6,000 persons, is presently the largest known plant in the USSR producing electronic computers. The plant originally was built in 1918 and, like the Penza plant, is part of a larger industrial complex. Formerly producing typewriters and office calculating equipment, the Moscow plant now has been converted to production of digital and analog computers. Some peripheral computer equipment and computer components (transistors, subminiature tubes, rectifiers, and memory devices) also are produced. In addition, this plant produces oscillographs and other measuring and recording devices for use with electronic computers. The manufacture of standard parts is done on an assembly line basis. Automatic assembly equipment of an unspecified nature (possibly automatic component insertion on printed circuit boards) was under development in 1959 for use in this plant. The structural elements of electronic computers are essentially standardized as in the Penza plant. Of the identified digital computers produced at this plant, the Strela and the Ural-I digital computers have been produced serially.* Only about 15 Strela computers were reported to have been produced before this computer was taken from production. The M-20, the fastest Soviet digital computer, also has been placed in serial production recently. Several models of the M-20 were seen

* For details on individual Soviet computers, see Appendix A.

by US visitors in the assembly area of the Moscow plant in mid-1959. Of the analog computers produced in this plant, the large MN-8 was reported in serial production in 1958, and a portable analog computer, the MN-M, was in serial production in 1959. The MN-M is planned to be one of the main production items of the plant. In 1956 this plant reportedly had 15 to 20 physicists working on the development of transistors. Of the 1,500 employees of this plant in 1956, 800 were reported to be engineers, mathematicians, and skilled technicians.

The Penza Computer and Analytical Machine Plant had a labor force of 4,000 employees in 1959. This plant has built experimental models of specialized digital computers, including the Pogoda, Kristall, and Granit. The Penza plant produces digital computers, some analog computers, electronic test equipment, card punches, and card reading devices. Many specialized computer parts are made in this plant, including ferrite cores and magnetic drums. Most of the more standard components such as capacitors, resistors, and electron tubes are supplied by the radioelectronics industry. The Penza and the Moscow plants produce the P80-2 perforator, the K80-1 controller, the C80-1 sorter, and the T5-M tabulator. Since 1950 the Penza plant has produced the ELI-15 electronic integrator. As early as 1949 the Penza plant built a computer designed by Gutenmakher, who often is associated with military projects for Scientific Research Institute No. 160. According to the Soviet press, in 1959, 14 to 15 percent of the total value of production of this plant was composed of office calculating equipment. The Penza plant is a part of a large complex that produces watches and heavy equipment. US visitors in 1959 reported seeing 24 Ural-I computers on the floor at Penza and reported the current production rate of this computer to be one every 4 days. The Ural-I computer was placed in serial production in October 1956 and is currently priced at 1.1 million rubles. The Ural-II -- to be priced at 1.5 million rubles -- is an improved version of the Ural-I and was placed in serial production in 1960. The price of the Ural-I now will be reduced to 800,000 rubles, according to a Soviet source. The Ural-I is produced in modular fashion and is composed of five cabinets or frames. Cabinets or frames almost identical with those of the Ural-I are used in the Pogoda computer and the MARS data-logging machine.

Like the Moscow and Penza Computer and Analytical Machine Plants, other plants producing office calculating machines could be converted in part or totally to production of electronic computers. There is no evidence that either the Kursk or the Ryazan' Analytical and Calculating Machine Plant has as yet produced anything other than office calculating machines. Considerable expansion (2.3 times) is

planned for the Ryazan' plant during the Seven Year Plan, however, and future production will include some electronic digital computers. 11/

The tremendous planned expansion of capacity at plants producing electronic computers under the Seven Year Plan emphasizes the importance that Soviet planning authorities attach to this sector of the electronics industry. In criticisms of the shortcomings of this sector, primary responsibility for the low output of computers was placed squarely on the "narrowness of the production base" (where production activities are "comparatively small, unspecialized" and at a low level of technology). 12/

C. Technology

1. Analog Computers

The USSR scored its earliest and most notable successes in both quantity and quality of production of electronic computers in the field of analog devices. At least 10 different types were in serial production by 1959, with several others in advanced stages of development. It is estimated that there are between 4,000 and 5,000 electronic analog computers in use in the USSR at the present time. This number is approximately the same as that of such machines in use in the US in scientific and industrial (nonmilitary) uses. These machines range from portable types capable of handling sixth degree equations to a large analog computer for solving equations up to the 32d degree. Serial production of the smallest analog computer, the partly transistorized MN-M, was reported to have begun in 1957, and approximately 300 probably had been produced by the end of 1958. The fully transistorized MN-10 was reported in serial production in mid-1958, although no confirmation of this point has been seen. Other analog computers that have been produced serially in the last few years are the MN-5, the MPT-9, and the IPT-5.*

Whereas the number of analog computers produced in the USSR is impressive, the accuracy of most of these machines, [redacted] is less than that of comparable Western computers. For machines of equivalent operating speeds (medium to real-time) this accuracy equates to an accuracy range of about 0.1 to 1 percent for Soviet computers and 0.01 to 0.1 percent for US computers. The greatest demand in industry, in military applications, and even in purely mathematical analyses is for real-time (or faster) machines -- that is, computers in which the solution occurs over the same (or shorter) time periods as the physical phenomena that are

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* For further details, see Appendix A, pp. 31 and 32, below.

being simulated. The absence of information about Soviet analog machines with accuracies of better than 0.1 percent does not, of course, prove an absolute inability to produce these machines, but the fact that the known serially produced machines are of the less accurate types suggests that at best only very small quantities of the better machines have been made. The voltage divider networks in most of the serially produced Soviet models have a stated accuracy of 0.1 percent, whereas voltage divider accuracies of 0.01 percent and better are commonplace in the US and are much easier to obtain than equivalent accuracies in the electromechanical components (such as servomultipliers, resolvers, and recorders) or in many of the electronic circuits (such as DC feedback amplifiers, arbitrary adjustable function generators, and electronic multipliers).

2. Digital Computers

In contrast to the relatively strong position of the USSR in the field of analog computers, there is evidence of a substantial lag in the Soviet position, relative to the West, in both the quantity and quality of production of digital computers. This lag has been candidly stated by Soviet computer specialists and economic planners, and measures to improve the situation are being undertaken at the present time. [redacted] production of at least three new or improved types of digital computers has been initiated recently. These models represent a degree of improvement over the earlier computers that is sufficiently impressive to permit their being referred to as a new generation of Soviet computers, although in many respects they are still less sophisticated than currently produced Western models. 50X1

Until 1958, Soviet digital computers that were serially produced were markedly inferior to their counterparts in the US and Western Europe. 13/ The Ural-I was the major production item in terms of quantity of production, yet it was a very bulky, unreliable, and slow machine by Western standards. It is believed that approximately 300 of these machines were produced by the end of 1958 and approximately 200 more by the end of 1960. The Strela computer, produced in much smaller numbers (about 15 units), was a larger and faster machine, although it also suffered from inherent limitations in reliability and flexibility. Even the BESM-I, the most advanced early Soviet digital computer, was comparatively much slower and less flexible than many standard serially produced US machines. Each of the above computers was based on vacuum tube technology, with some use of semiconductor diodes. None of the Soviet digital computers was designed to incorporate a high-speed magnetic core internal

storage, although a core storage was incorporated into the BESM computer in 1957.*

Each of the computers mentioned above was originally designed during 1952-53, and no major technological improvement was incorporated into machines being serially produced from that time until 1958. Intensive research and development continued, however, and single units of more advanced types of general and special-purpose computers were fabricated. During 1957 and 1958, there were received reports which indicated that production of both the Ural-I and the Strela were to be discontinued.** In 1959, data that indicated the nature of the new machines to be produced became available. This information, in combination with official announcements concerning the scheduled growth of computer production under the Seven Year Plan, permits the formulation of a more comprehensive estimate of future developments in Soviet digital computers than has heretofore been possible.

Initial production of the M-20 computer on a serial basis probably began late in 1958 or early in 1959. Production of the Ural-II was initiated in 1960. An improved version of the BESM (the BESM-II) also has been reported to be in serial production in late 1960, but there is no firm indication that present plans call for large-scale production of these computers.

Each of the above computers incorporates internal magnetic core storage together with magnetic drum and tape memories. The slowest of these newer digital computers, the Ural-II, is capable of an average speed of 5,000 operations per second. The BESM-II reportedly will operate at between 8,000 and 10,000 operations per second, and the M-20 will accomplish approximately 20,000 operations per second. The new computers thus represent a considerable improvement in memory access and speed of operation compared with earlier models. The average speed figures quoted for Soviet machines are comparable with the range of 20,000 to 25,000 operations per second that is typical of the large US scientific machines in serial production as of 1959. These figures on speed are a somewhat ambiguous measure of merit, as they relate only to the central computer itself and, taken alone, are not a precise measure of the over-all capabilities of a general-purpose computer. These figures are included here primarily to indicate that at least in this parameter the better Soviet machines are relatively close to good Western computers. In most other respects these new Soviet computers compare unfavorably

* For further details on Soviet digital computers, see Appendix A.
** The Ural-I apparently will remain in production after production of the Ural-II has begun.

with current Western models. The Ural-II, BESM-II, and the M-20 are all still based on vacuum tube technology rather than on transistors. A completely transistorized computer, the Razdan, is still under development and probably will not be ready for production until 1961. The first fully transistorized US computer (TRADIC) was completed in 1954. Input-output equipment and primary memory storage systems of Soviet computers are technologically 2 to 3 years behind current Western practice, and no extensive use is being made of input and output buffering. The internal organization of the Soviet machines (such as number representation and range, format and number of instructions, and clock rate) is quite similar to that of US machines of about 2 to 3 years ago. 14/

D. Problems and Shortages

As previously noted, the USSR has shown a distinct interest in and a relatively good capability for standardizing and mass-producing a series of electronic analog computers for routine use in schools, in scientific laboratories, and in industry. Although the majority of known types do not exhibit the better characteristics of standard Western models, they are clearly adequate for a wide variety of military as well as educational, scientific, and industrial purposes.

In contrast to the success achieved in production of analog computers, there is a substantial body of evidence that places the USSR in a distinctly unfavorable position, compared with the US, in the area of general-purpose digital computers. The factors governing requirements for computers have not, of course, been identical in both countries. In the US the potential demand for computers for processing business data resulted in an early emphasis on production of digital computers that could not be expected to occur in the USSR. In spite of this factor, however, it is clear that there is a substantial lag in the production of digital computers in the USSR which cannot be satisfactorily explained by the absence of requirements.

This lag stems from a series of problems that continue to plague the Soviet computer industry. In spite of the importance of electronic computers to the automation of industry and to the control and guidance of satellites and missiles, production of electronic computers still appears to be a victim of past and present inadequate planning and priority, especially in the nonmilitary sector. Poor planning in the electronic computer industry, according to Soviet admissions, has resulted in all the following situations: (1) inadequate production capacity, (2) poor quality and insufficient quantity of components suitable for electronic computer production, (3) shortages of trained computer specialists, (4) unspecialized production

plants, (5) excessive time lags between the development and production of computers, (6) too lengthy testing and installation times, and (7) inadequate allotments of material to plants.

The President of the Academy of Sciences, A.N. Nesmeyanov, reported in 1957 that "the number of machines /high-speed computers/ available entirely fails to satisfy the rapidly increasing demand for mathematical computations." 15/ Early in 1958, Academician A.A. Blagonravov stated that electronic computers must be given preferential treatment and charged that shortcomings in planning largely explained the lack of production of high-speed computers. He stated further that such fully tested computers as the BESM, the M-2, and the M-3 should have been in serial production but were only one of a kind. In February 1958, there was no plan for the development of computer engineering in the immediate future. 16/ Under the Seven Year Plan, verbal emphasis has been placed on developing production of electronic computers. In the spring of 1959, however, there were continued complaints that the coordinating Scientific and Technical Committee for Computer Technology was completely inactive and that the Leningrad sovnarkhoz was quite disinterested in organizing serial production of electronic computers in the Leningrad area, a criticism that had been raised as early as 1957. 17/ The newly constructed Leningrad Experimental Computer Plant apparently is intended as a site for serial production of electronic computers.

Perhaps the most serious problem retarding production and quality of computers is the poor quality and inadequate supply of components, which was blamed on poor planning in the radioelectronics industry. Without quality components, reliable machines cannot be produced. Semiconductors produced for electronic entertainment equipment are unreliable for use in computers. In the USSR, as in the US, the standard procedure has been to produce many of the components as well as most peripheral equipment for computers in plants producing computers. In the USSR, approximately 20 organizations that are engaged in research and development of computers also produce equipment for computers. The lack of standardization and the waste and delay in the serial production of computers are reflected in the inadequate quantity and quality of components produced. 18/ In mid-1959 this problem was further elaborated in the Soviet press:

> Experience indicates that the rapid introduction of computer machinery into industry is being impeded by insufficient standardization of the components and assemblies of machines. For this reason, the development of each new machine requires the efforts of large scientific staffs. If the problem of standardization were solved and the production of standard components

> and subassemblies were organized, even plant laboratories and design bureaus could develop and design mathematical and control computers.
>
> To make components and assemblies of control machines, reliable electronic devices and components are urgently needed, especially crystal triodes (transistors) and diodes, ferrite matrices and rings, delay lines, miniature resistors and capacitors, and other devices and components. The demand for these components is so great that often industry is unable to satisfy it. 19/

The future improvement of electronic control machines will depend mainly on production of high-quality semiconductors, magnetic devices, and radio components as well as on the scientific research done in physics and electrical engineering. 20/ The USSR is moving rapidly in the development of production capability in semiconductors and magnetic devices for computers but still lags behind the West in the quantity and range of types produced.

Other serious problems are the inadequate plant capacity for the assembly of electronic computers and the absence of product specialization in Soviet plants. According to the Soviet press in December 1958, the principal reason for the lack of computer production was the "narrowness of the production bases." 21/ At present, only two known computer plants of any size are in operation, but at least five other computer plants are scheduled to be placed in operation in the near future.

The problem of inadequate plant facilities in the USSR for producing electronic computers has contributed to the excessive time formerly required from the beginning of the development to the final production of electronic computers. For example, the small M-3 digital computer was designed in 1954, built in 1956, and haggled over by Gosplan for a full year before being placed in serial production in 1958. 22/ The excessive time of 2 to 3 years required for development and construction of new experimental models of electronic computers was blamed mainly on the shortage of adequate facilities for experimental production. In 1958 the Moscow plant was criticized for being slow in carrying out experimental operations. The experimental computer plants recently built in Leningrad and Yerevan are evidently intended to help alleviate the serious shortage of facilities for building experimental computers.

Another frequently mentioned problem is the insufficient quantity and often poor quality of digital input-output equipment, a factor that significantly lowers the effectiveness of existing

machines and impedes their use for automation of production processes. In addition to improvements in design, the standardization of this equipment is urgently needed. Reportedly it was planned to develop a single line of standardized peripheral units for use in conjunction with components and to begin serial production of such equipment. 23/

Reported shortages of engineers and programing mathematicians have been blamed for delays in checking out computer equipment at the installation points. In the USSR, according to reports, up to 6 months were required for adjusting a machine after installation. 24/ As early as 1956 it was charged that absolutely nothing had been done to train skilled electronic computer mechanics. 25/ In 1957, there reportedly were 4,500 students studying automation at the Institute of Automatics and Telemechanics in Moscow. Of this number, 1,500 were specializing in some phase of computer work. After graduation, most of these students, however, go into analog computer work. It was reported that there are too many theorists and not enough applied scientists in the field of automation. 26/ In 1958 the computer specialist A.P. Yershov stated that Moscow University alone graduates 250 to 300 mathematicians annually, of whom approximately 100 specialize in computer work. 27/ Referring directly to the shortage of trained computer specialists in industry, A. Petrov of the Penza Computer Plant reported in 1959 as follows:

> **The output of electronic computing machinery will increase every year, but even now this young branch of industry is experiencing a shortage of radio-electronic engineers and programing mathematicians. At the Penza plant the shortage of cadres is the cause of delivery delays which can run into 2 or 3 months: the completed machines must be tuned up and tested, and the shortage of experts in this field delays their completion. Last year the plant had planned to obtain 50 experts in this field, but it received only 7, and the shortage has to be made good by employing specialists in allied fields who have to be retrained. True, the Ministry of Education has worked out an extensive program for the training of such specialists, and, as from this year [1959], experts in such fields will be specially trained. 28/**

In 1959, P.D. Lebedev and other Soviet specialists who visited the US admitted that there was still a shortage of engineers in the field of electronics and computer technology. 29/ Computer specialists presently in training in theory and production probably will alleviate this problem.

The need to standardize methods of constructing electronic computers and to design individual computers composed of identical parts, a practice that is carried on in the US, has been stressed in recent Soviet statements. 30/ In addition, Soviet industrial specialists do not believe that their computer plants are sufficiently mechanized. According to A. Petrov, a computer specialist at the Penza plant, "It is paradoxical that at a plant which is producing complicated machinery for the automation of production [so much] manual labor is still employed. As a result," he concluded, "production costs rise to impressive heights." To reduce costs, he suggested the use of printed circuits with an annual saving of 1 million rubles. Printed wiring is employed in the USSR and has been used since 1957, but specialized production of printed wiring panels at a Moscow plant was still not underway by the end of 1958. 31/ Wiring on boards, but not printed circuitry, was used in the research model of the EMU-8 built by the Institute of Automatics and Telemechanics, which was on display at the Soviet exhibition in New York in 1960.

Shortages of materials other than electronic components also have been blamed on inadequate planning and priority. In 1958 the lack of allocations of materials hampered the Penza plant in its production of computing and tabulating machines for census taking. 32/ A Soviet visitor to a US electronics plant complained that it was even difficult to obtain a sufficient quantity of insulated wire and cable for wiring such priority projects as computers and automatic control apparatus. 33/

The illustrations of production problems and component shortages in the field of digital computers cited above probably reflect a genuine concern on the part of industry officials over the planning difficulties that are encountered in this complex and rapidly growing sector of the electronics industry. These official self-criticisms probably are overstated somewhat, however, as recent developments in the growth of output of computers and in the improvements in quality of Soviet machines show that this equipment is a sector of the electronics industry which, while presently lagging behind domestic needs, is vigorous and strong. Because of the apparently strict apportionment of computer time to projects of highest priority, present shortages of digital computers probably have not seriously hampered critical research efforts or military projects.

III. Utilization of Electronic Computers in the USSR

In the USSR, as in the US and other industrial nations, the electromechanical and electronic analog computers became stock items of production well in advance of the stored program digital machine, although

at present the digital computer is economically more significant in both the US and the USSR. In the USSR, however, this point was reached only in 1959, whereas in the US the annual value of production of digital computers surpassed the value of analog types several years ago. This heavier emphasis on analog machines in the USSR, coupled with the relatively small total production effort in computers compared with that in the US, has placed the USSR in a position of general short supply of digital computers insofar as wide-scale use in low-priority areas is concerned.

Although approximately 50 percent of the annual value of digital computers produced in the US are used in routine problems of business statistics and data handling, the remaining 50 percent, which is devoted to military, scientific, and engineering purposes, is still far in excess of the total annual Soviet production of digital computers. As a result, the USSR has been unable to utilize digital computers to the same extent as the US in other than high-priority efforts. In spite of widely publicized plans for extending the use of computers, nonmilitary applications are still largely in the planning or testing phase. Experimental applications are underway in the automation of the chemical, oil, steel, and machine tool industries; in economic planning and accounting; in automatic language translation; in weather forecasting; and in medical diagnosis. Expanded applications of computers in these areas can be expected during the current Seven Year Plan.

In the USSR, electronic computer centers are being established at dispersed locations to be used as local computational centers for a wide variety of economic, industrial, and scientific problems. Ultimately it is planned that each oblast will have its own local computer center. Ural-I and Strela digital computers and the EMU series of analog computers apparently are standard items for use in existing computer centers.

The primary computer center of the USSR is the scientific and technical center of the Academy of Sciences in Moscow. This center has a Strela computer and a BESM as well as a very large analog computer containing 300 operational amplifiers. These amplifiers have a stated accuracy of 0.1 to 1 percent. In addition to this primary center, there are approximately 60 other computer centers in the USSR specialized to serve different localities and different branches of industry. Some of these centers are closely associated with universities and higher technical schools or with scientific research institutes and laboratories. Although it is planned that the computer centers will allocate time for industrial and economic statistical work, little progress has been noted as yet on the large-scale use of computer centers for these purposes. An economic journal

of early 1960 complained that serial production of electronic computers for statistical accounting, economic planning, and production management had not been initiated as of March 1960. [redacted] 50X1
[redacted] it is not only the development of electronic computers 50X1
that is retarding the plan for the automation of industry but also the development of other devices for application to automation. 34/

The Seven Year Plan emphasizes the need for the development and production of electronic computers for the control of industrial processes because of the role of electronic computers in industrial automation, a vital factor in increasing production. Sectors of the economy reported to be first in line for automation include the chemical, steel, and oil industries and the electric power network. Research is being carried on for the automation of these industries.

In the steel industry, analog computers will be applied to rolling steel and open-hearth furnaces for control of the fuel-air ratio and the fuel mixture when different fuels are used. 35/ A transistorized computer was developed for the automatic control of electric steel-smelting furnaces. 36/

In 1959 an electronic computer was in process of development for the control of electric power networks. The formulated plan is to design an electronic computer that will control electric power flow in the contemplated united power network for the European part of the USSR. 37/

In the chemical and oil-refining industries, industrial control will first be effected in shops where working conditions are harmful to health. 38/ In the oil industry an analog computer, the EIS, was developed and phased into operation in 1958 for determining both the number of oil wells and the method of extraction according to the form and volume of the strata. 39/

In 1959, in the rubber goods industry, the rubber footwear plant in Moscow had an automatic control and signaling machine, the MARS-300, which guides 48 presses producing rubber footwear. It is planned that the MARS machine will soon be placed in serial production. 40/

In the machine tooling of metal parts, the use of program control of machine tools is capable of reducing the time for processing by 40 to 50 percent, according to a statement by Khrushchev. 41/ Analog computers for program control of machine tools were exhibited at the Brussels World's Fair in 1958. This equipment was not production equipment but was built in institutes. Other electronic computers to be used in automation include the transistorized analog computer

MN-10 for controlling production processes and the Kiev digital computer for computing production processes. 42/

Weather forecasting with the use of electronic computers apparently is carried out on an experimental basis. The shortage of computer time available on high-speed computers for this purpose is hampering numerical forecasting research in the USSR. The BESM-I is a general-purpose computer used for weather forecasting, but machine time on this computer is limited. The slow Pogoda computer, installed at the Central Institute of Forecasting in Moscow in 1958, as well as the Granit computer, are specialized computers used for weather forecasting. 43/

In the USSR, as in the US, general-purpose digital computers are used for research in mechanical language translation. Experiments in machine translation began in Moscow in 1955 and in Leningrad in 1957. At least six Soviet research facilities* are known to be working on machine translation. 44/ At the present time a BESM computer is being used part time for English to Russian translation and a Strela computer part time for French to Russian. For purposes of translation, these computers are considered to be slow and have a very small storage capacity. A 900-word English vocabulary is in use with the BESM, although the computer specialist, Dorodnitsyn, stated that a special machine with a storage of 10,000 to 20,000 words and greater speed was required. 45/ Print readers have not yet been produced in the USSR, but a cipher reader with a speed of 120 ciphers per second has been developed for reading such items as checks, invoices, and bank statements. 46/

The USSR also has used electronic computers for medical purposes such as diagnosis, brain simulation research, and the study of nervous activity related to fatigue. At the Kiev computer center, computers were used for diagnosis for heart surgery. 47/

The implementation of plans for wider use of analog and digital computers in nonmilitary elements of the economy of the USSR is dependent on the success attained in meeting planned increases in productive capacity. The planned growth of computer production does

* The Institute of Mechanics and Computer Techniques in Moscow; the V.A. Steklov Mathematical Institute of the Academy of Sciences of the USSR; the Linguistics Institute of the Academy of Sciences of the USSR in Leningrad; the Machine Translation Laboratory of the Leningrad University; the Computing Center of the Academy of Sciences of the Armenian SSR in Yerevan; and the Electronics, Automation, and Telemechanics Institute of the Academy of Sciences of the Georgian SSR in Tbilisi.

imply a significant annual increment in available computer capability, some of which can be increasingly allocated to economic and industrial use. As an example, the estimated production of digital computers in 1960 could have been as much as 220 Ural-II computers or 65 units of the M-20. Rather than either of these extremes, it is estimated that about 100 units of the Ural-I or Ural-II and from 20 to 25 units of the M-20 would have been produced in 1960, accounting for a value of about 200 million rubles. The remaining 130 million rubles would have been devoted to constructing special prototype units and some production of small numbers of special types, such as the Kiev, the BESM-II, and the Aragat.

It is believed that at least through 1961 the Ural-II and the M-20 will be the principal serially produced digital computers. By about 1962 the present research and development on a fully transistorized computer probably will result in another change in production line models. Also considered probable is that this change will bring with it additional improvements in machine organization, input-output devices, and memory capabilities which in turn will further enhance the over-all capabilities of computers used in military and scientific applications. In particular, some improvement should occur in the capability of Soviet digital machines to handle large quantities of data more rapidly and with more flexible programing. During 1960-65, production of digital computers will continue to grow more rapidly than production of analog computers. The use of digital computers for handling business data (such as inventory records and financial accounting) and for industrial control probably will remain small compared with military and scientific uses and will continue to lag considerably behind the West through 1965. There probably will be, however, a noticeable increase within the next 2 years in the use of computers for regional and aggregative economic planning and for other governmental activity such as census work and computations of plan fulfillment statistics.

IV. Soviet Trade in Computers

Soviet trade in electronic computers is economically insignificant, although individual exports have been widely publicized. On several occasions the USSR has attempted to import Western computers, but the trade control restrictions on such items have limited actual purchases to a relatively small number, involving computers and computer components of modest capability. There has been little interest shown by the USSR in purchasing significant numbers of nonembargoed computers.

Within the Sino-Soviet Bloc the USSR is by far the dominant producer of electronic computers. A few Soviet computers, both analog and digital types, have been exported to other Bloc countries. Exports

of digital computers have been widely publicized. The USSR also has participated in the development of computer production in other countries of the Bloc and has trained numerous computer specialists from these countries. Intra-Bloc negotiations and transactions concerning electronic computers have been observed between the USSR and Communist China, East Germany, Poland, Rumania, Czechoslovakia, and Hungary.

The USSR plans to export a Ural-I to East Germany for its Academy of Sciences. Analog computers also may be sold to East Germany for use in German industry. 48/ Czechoslovakia received a Ural-I computer in February 1959. Two Czechoslovak computer specialists have worked with a Soviet computer specialist on miniaturization of electronic circuits. 49/

Poland and Rumania have been aided by Soviet experts and completed the construction of their first electronic computers in 1959. The first Polish computer was made for the Polish Hydrometeorological Institute. The first Rumanian computer, with a speed of 15,000 operations per second, was developed at the Rumanian Polytechnical Institute. 50/

In 1958, Hungary was in the process of building the Soviet-designed M-3 electronic digital computer, using Soviet components, after having been unable to purchase a Ural-I in 1957. 51/ A 1959 Soviet offer of a Ural-I to Czechoslovakia at 900,000 rubles reflects a price reduction of 200,000 rubles below the price of these computers reportedly in the USSR in 1959.

The USSR also has given Communist China considerable aid in developing and building digital computers, in training Chinese specialists in computer technology in the USSR, and in providing Soviet computer components. Top Soviet computer specialists have traveled frequently to China, and 50 Chinese students were reported studying computing design at the Institute of Precision Mechanics and Computation Technology in Moscow in 1957. Models of the Soviet-designed M-3 and BESM-II digital computers have been built at Chinese institutes. 52/

The most widely publicized computer transaction with the Free World was the Soviet gift of a Ural-I computer to India. Although final delivery occurred 2 years after the planned delivery date of 1956 and although many difficulties and delays were experienced in installing the machine, the USSR reaped valuable propaganda results from the gift. Final assembly of this machine was completed in November 1958. 53/

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APPENDIX A

ELECTRONIC COMPUTERS PRODUCED IN THE USSR, BY PRODUCING FACILITY

Plant Name and Location	Production: Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Moscow Computer and Analytical Machine Plant, 35 Nizhnyaya Krasnosel'skaya Ulitsa, Moscow, RSFSR 55/						This calculator plant was founded in 1918. This plant serially produces electronic analog computers, digital computers, and electromechanical integrators. It also produces components (transistors, subminiature tubes, ferrite cores, and photodiodes) and peripheral equipment (storage devices; oscillographs; and phase, frequency, and volt meters). The plant is reported to produce all accessory apparatus and most individual parts.
	Analog	MN-8 56/	1955	71 as of Nov 1957	N.A.	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer was recommended for serial production in 1957, and serial production began in 1958. A large electronic simulator, this is the most powerful nonlinear analog computer produced in the USSR. This computer, which can simulate flight, weighs 6,000 kg, has 2,500 electron tubes and 8,650 germanium diodes, is sectional in design, and can solve differential equations to the 32d order. This computer has 32 integrating linear modules.
		MN-M 57/	1956	300 as of the end of 1958	N.A.	Designed by V.V. Ushakov and G.M. Petrov of the Scientific Research Institute of Computers. This computer was placed in serial production in September 1957. This is a portable nonlinear analog computer, said to be the smallest analog computer produced in the USSR. It is partly transistorized and has some subminiature tubes. It is designed for use in institutes, design bureaus, educational facilities, and industrial plants. It can simulate flight and can solve differential equations to the 6th order. This computer was displayed at the Brussels World's Fair in 1958.

Plant Name and Location	Production: Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Moscow Computer and Analytical Machine Plant	Digital	Ural-I 58/	1953 (design) 1955 (production)	450 to 500 as of the end of 1960	1,100,000 (to be 800,000)	Designed by Y.V.Ya. Basilevskiy of the former Ministry of Instrument Building and Means of Automation. Production of this model includes those produced at the Penza plant. Serial production began in November 1956. This is a small, binary, serial, single-address, fixed-point digital computer, the average speed of which is 100 operations per second. It is used at various scientific research institutes and industrial computing bureaus for engineering calculations and weather forecasting. After the Ural-II goes into serial production, a price reduction is to go into effect. Comparable US types include the NCR-102d and the IBM-650.
		M-2 59/	1952-53	2 to 3	750,000	Designed by I.S. Bruk of the Power Engineering Institute of the Academy of Sciences, USSR. This is a medium-size (by Soviet classification), general-purpose digital computer that has an average speed of 2,000 to 3,000 operations per second and occupies 22 square meters. Although it was modernized in 1954, plans were announced in 1956 to increase the speed to 50,000 operations per second. This computer, although not in serial production, is used in various scientific fields, such as nuclear physics, radio electronics engineering, and power economics, and is designed for future use in industrial automation and operation. This computer has been said to be 10 times cheaper than the Strela. The comparable US type is the IBM-650.
		Strela 60/	1953	About 15	5,000,000 to 7,000,000	Designed by Y.V.Ya. Basilevskiy, the principal designer, and N.P. Brunsentsev of the Institute of Precision Mechanics and Computation Technology of the Academy of Sciences, USSR. This computer, which was developed for industry, was put into serial production in 1956, although production is now discontinued. The Strela, a large digital computer occupying 200 square meters, was built to the requirements of the individual consumer. It is a binary, parallel, three-address computer with an average speed of 2,000 to 3,000 operations per second and is used for weather forecasting and French-Russian translation. One Strela, at the computing center of the Moscow Academy of Sciences, was connected to a teletypewriter communications network.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Moscow Computer and Analytical Machine Plant	Digital (Continued)	M-20 61/	1956	35 to 40 as of the end of 1960	4,000,000	Designed jointly by S.A. Lebedev of the Institute of Precision Mechanics and Computation Technology of the Academy of Sciences, USSR, and Sulim of an industrial institute. Production of this computer, which was in serial production in 1959, was recently reported to be one every fourth day. This is a binary, floating-point, three-address digital computer that has an average speed of 20,000 operations per second. This computer is of standard design, its power (without cooling system) is 47 kw, and it occupies 200 square meters. The comparable US type is the Sperry Rand Univac 1103.
Penza Computer and Analytical Machine Plant, 44 Karazavodskaya Ulitsa, Penza, RSFSR 62						This plant, which is subordinate to the Penza sovnarkhoz, employs about 4,000 people in production of special-purpose and general-purpose analog and digital computers and most of the peripheral equipment and components, including magnetic drums. The plant has its own design bureau. In 1959, 14 to 15 percent of production consisted of calculators and adding machines. This plant produced a large number of relay-operated machines for high-speed processing of data for the all-union census. The Seven Year Plan calls for a 100-percent increase in production capacity through new construction.
	Analog	ATR-1 63/	1954	N.A.	56,000	Both the designer and the users of this machine are unknown. This is a highly specialized analog computer used for traction calculations.
		ATR-2 64/	1956	N.A.	N.A.	Both the designer and the users of this machine are unknown. This is a highly specialized analog computer used for heat calculations.
	Digital	Ural-I				(See p. 26, above.)
		Ural-II 65/	1959 (prototype) 1960 (production)	25 to 30 as of the end of 1960	1,500,000	Designed by B.I. Rameyev, plant director. This is a binary, parallel, single-address, fixed and floating point digital computer that has an average speed of 5,000 operations per second and an input-output register for real-time communications lines. This computer has accuracy to 10 decimal points, carries 30 instructions, has a cycle duration of 10 microseconds, and occupies 40 square meters. Possibly it went into serial production in 1960.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Penza Computer and Analytical Machine Plant (Continued)	Digital (Continued)	Pogoda (STsM-25) 66/	1957-58	1	N.A.	Designed by N.G. Maslov of the Design Bureau at the Penza plant. This is one of the smaller specialized digital computers used for solving a definite range of meteorological problems. It also is adaptable for geodetics and cartography. It has an average speed of 200 to 400 operations per second. This computer is installed at the Central Weather Institute for use in long-range meteorological forecasting.
		Kristall 67/	1957	1	N.A.	Designed by Yu.N. Belikov of the Design Bureau at the Penza plant. This computer was installed in 1959 at the Karpov Institute of Physical Chemistry in Moscow to perform calculations on treatment of X-ray analysis of crystalline matter. It is a slow machine (200 operations per second) used in chemical research and in determination of crystalline structure.
		Granit 68/	N.A.	1	N.A.	Designed by V. Przhiyalkovskiy of the Design Bureau at the Penza plant. This is a special-purpose digital computer for the solution of statistical problems and for weather forecasting.
Computer Center of the Ukrainian Academy of Sciences, Kiev, Ukrainian SSR 69/						The computer center is housed in a new four-story building on the outskirts of Kiev at the intersection of Dobryyput Ulitsa and Kitayevskaya Ulitsa.
	Analog					No production has been reported.
	Digital	MESM 70/	1952	1	N.A.	Designed by S.A. Lebedev of the Computer Center of the Ukrainian Academy of Sciences. Development of this computer began in 1942. It is a small, three-address digital computer that has an average speed of 50 operations per second. It is used for solving practical problems and for training purposes.
		SESM (Tsepnik) 71/	1957	1	N.A.	Designed by S.A. Lebedev, Rabinovich, and Blagoveschevskiy of the Institute of Precision Mechanics and Computation Technology of the Academy of Sciences, USSR, and V.M. Glushkov of the Computer Center of the Ukrainian Academy of Sciences. This is a special-purpose digital computer for solving linear algebraic equations of up to 400 unknowns in hydrotechnology, architecture, and machine design. It occupies 8 square meters.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Computer Center of the Ukrainian Academy of Sciences	Digital (Continued)	Kiev 72/	1960	1 to 2	1,500,000	Designed by V.M. Glushkov and L.N. Dashevskiy of the Computer Center of the Ukrainian Academy of Sciences. This is a general-purpose digital computer for solving complex mathematical problems in computing production processes for industrial enterprises such as steel, chemical, and oil processing. It is a binary, parallel, three-address, fixed-point computer of standard modular design that occupies 30 to 40 square meters and has an average speed of 5,000 to 6,000 operations per second. One of these computers is to be sent to the Joint Nuclear Research Establishment at Dubna.
		STsM-12 73/	N.A.	1	N.A.	Designed by the Ukrainian Academy of Sciences. The characteristics of this machine are unknown.
Experimental Computer Plant, Leningrad, RSFSR 74/						In 1958 this new plant, subordinate to Gosplan, USSR, was to begin production of electronic computers as well as calculators. A capacity for production of 10 million memory elements per year was to be installed. No production for this plant was reported through 1960.
Ryazan' Analytical and Calculating Machine Plant, Ryazan', RSFSR 75/						Reportedly this plant was converted to production of electronic computers in January 1960, when 428 workers, engineers, and technicians were taking special courses. No production was reported for this plant through 1960.
Experimental Plant of the Yerevan Institute of Mathematical Machines, Yerevan, Armenian SSR 76/						Construction of this plant began in 1957. It is to produce serially high-speed electronic computers of various types as well as models of developmental computers and general-purpose and specialized computers, including computers for process control. No production was reported for this plant through 1960.
	Analog (None)					
	Digital	Razdan 77/	1959	Serial production planned	N.A.	Designed by S.N. Mergelyan of the Yerevan Institute of Mathematical Machines. Development of this machine was begun in 1957. This is a transistorized digital computer for use in scientific research institutes, design bureaus, and large enterprises. It has an average speed of 4,000 to 6,000 operations per second.

Plant Name and Location	Production: Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Unit Price (1955 Rubles)	Remarks
Experimental Plant of the Yerevan Institute of Mathematical Machines	Digital (Continued)	Aragats 78/	1959	Serial production planned	N.A.	Designed by S.N. Mergelyan of the Yerevan Institute of Mathematical Machines. This machine, which has an operating speed of 10,000 to 20,000 operations per second, is for use in planning and design bureaus and enterprises. One of these computers was to have been delivered to Leningrad University in 1960.
		Yerevan 79/	1959	Serial production planned	N.A.	Designed by S.N. Mergelyan of the Yerevan Institute of Mathematical Machines. This is a general-purpose, vacuum-tube computer, which has an operating speed of 2,000 to 8,000 operations per second, for use in large design bureaus, computing centers, and enterprises. It is of simpler design than the Aragats.
Electronic Computer Plant, Estonian SSR 80/						This plant was under construction in 1958. No production for this plant has been reported.
Unnamed Computer Plant, Minsk, Belorussian SSR 81/						No production for this plant has been reported.
Unnamed Computer Plant, Taganrog, RSFSR 82/						No production for this plant has been reported.
Vil'nyus Computer Plant, Ukmerge Ulitsa, Vil'nyus, Lithuanian SSR 83/						Construction of this plant, which began in 1957 and was still underway in 1959, was begun by the Chief Directorate for the Precision Instruments Industry. Micromotors for the computers built by this plant are to be produced by the Elfa Electrotechnical Plant in Vil'nyus. Plans called for production to begin in 1959. The first perforating machines for computing centers were produced in May 1959.
Unknown	Analog	IPT-4 84/	1950	N.A.	321,400	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This is a linear electronic analog computer for solving scientific and technical problems involving ordinary differential equations to the 6th order. It has six integrating linear modules and weighs 1,000 kg. This computer was in serial production in 1956 and 1958.

Plant Name and Location	Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Unknown	Analog (Continued)	IPT-5 85/	1950	N.A.	182,800	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer, which went into serial production in 1958, is a linear electronic modular analog computer for solving scientific and technical problems involving ordinary differential equations to the 9th order. This is a real-time computer that weighs 500 kg. It was in use at the Kazakh Academy of Sciences in 1958.
		MPT-9 86/	1952	N.A.	569,000	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer, which went into serial production in 1958, is a medium-capacity linear electronic sectional analog computer for solving scientific and technical problems involving ordinary differential equations to the 16th order. This computer is a simulator, has 16 integrating linear modules, and weighs 1,800 kg.
		ML-2 87/	1955	N.A.	N.A.	The designer of this computer is unknown. This is a linear electronic analog computer for solving algebraic equations to the 12th order. It has 12 integrating linear modules.
		MPT-11M 88/	1953	N.A.	530,000	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This is a nonlinear modular analog computer for solving scientific and technical problems involving differential equations to the 6th order. It was modernized in 1956 and was in serial production in 1956 and 1958. This computer, which was used in 1959 for research in processes of automatic regulation, has six integrating linear modules and weighs 350 kg.
		MN-1 89/	1955	1,000 as of 1959	N.A.	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer, which was recommended for serial production in 1956, is a nonlinear sectional analog computer of medium capacity. It will solve ordinary differential equations to the 12th order, has 12 integrating linear modules, and weighs 3,000 kg.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Unknown	Analog (Continued)	MN-2 90/	1955	N.A.	53,800	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This is a nonlinear electronic analog computer for solving scientific and technical problems involving differential equations to the 6th order. It has six integrating linear modules and weighs 1,500 kg. In 1956 this computer was being produced in individual units.
		MN-3 91/	N.A.	N.A.	N.A.	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer is used for solving scientific and technical problems.
		MN-5 92/	N.A.	N.A.	N.A.	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This computer was in serial production in 1958.
		MN-7 93/	1955	N.A.	N.A.	Designed by the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This is a low-power, table-model, nonlinear electronic computer with a small capacity. It is used for simulating automatic control processes and is intended primarily for the development of systems for automatic regulation of manufacturing units and technological processes. It has six integrating linear modules, will solve ordinary differential equations to the 6th order, and weighs 170 kg. It was in serial production in 1956 and 1958.
		MN-10 94/	1957	N.A.	50,000	Designed by G.V. Grigoriyev and Petrov of the Scientific Research Institute of Computers. This is a small, completely transistorized, nonlinear analog computer. It contains 653 semiconductor diodes and triodes. This computer is to be used in creating other analog computers for controlling production processes. It will solve ordinary differential equations to the 6th order. Serial production of this computer began in 1958.
		MN-11 95/	1959	N.A.	N.A.	The designer of this machine is unknown. This computer, which will direct 100 production parameters, is to be used for controlling production processes.

Plant Name and Location	Production: Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Unknown	Analog (Continued)	MN-12 96/	N.A.	N.A.	N.A.	The designer of this machine is unknown. This is a special-purpose computer, housed in three cabinets. One of these computers is being used by a three-stand continuous cold-reduction strip mill.
		EMU-(?) 97/	N.A.	N.A.	500,000 to 1,000,000	Designed by the Institute of Automatics and Telemechanics in Moscow. This is a large-capacity nonlinear analog computer that will solve ordinary differential equations to the 40th order. This is a custom-built computer of sectional stand design. It has a general-purpose section as well as one for special-purpose applications such as aero-dynamics and motors. This computer has 40 integrating linear modules.
		EMU-(?) 98/	N.A.	30 to 50 per year	500,000 to 800,000	Designed by the Institute of Automatics and Telemechanics in Moscow. This is a medium-capacity nonlinear analog computer that will solve ordinary differential equations to the 16th order. It is used for research and design on such problems as surface movement. It has 20 integrating linear modules.
		EMU-(?) 99/	N.A.	50 to 100 per year	300,000 to 500,000	Designed by the Institute of Automatics and Telemechanics in Moscow. This is a medium-capacity linear analog computer that will solve ordinary differential equations to the 16th order. It is used for research and design of equipment and systems that emphasize stability. It is of sectional construction, having two parallel parts, and has 20 integrating linear modules.
		EMU-(?) 100/	N.A.	150 to 300 per year	30,000 to 50,000	Designed by the Institute of Automatics and Telemechanics in Moscow. This is a small-capacity nonlinear analog computer that will solve differential equations to the 16th order. It is a small-scale, table-model computer for use in research and design of separate installations. It has sixteen integrating linear modules, a simplified control diagram, and hand-tuning.
		EMU-5 101/	1955	N.A.	N.A.	Designed by B.Ya. Kogan of the Institute of Automatics and Telemechanics in Moscow. This computer was in production in 1956.
		EMU-6 102/	1955	N.A.	N.A.	Designed by B.Ya. Kogan of the Institute of Automatics and Telemechanics in Moscow. This computer is larger than the EMU-5.

Plant Name and Location	Production: Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Unknown	Analog (Continued)	EMU-7 103/	N.A.	N.A.	N.A.	Designed by B.Ya. Kogan of the Institute of Automatics and Telemechanics in Moscow. This computer, which was in serial production in 1959, was developed for research on complicated automatic systems. A laboratory model was on display at the Soviet exhibition in New York in 1960.
		ATR-1				(See p. 27, above.)
		ATR-2				(See p. 27, above.)
		EIS 104/	1954-55	N.A.	N.A.	Designed by Nikolayev of the All-Union Petroleum and Gas Scientific Research Institute and Aleksandrov of the Penza plant. This computer was being used by the Research Institute of the Petroleum Industry for calculating subsoil hydraulics and crude oil deposits in 1957. It was reported to have been used successfully in 1959 for exploring deposits. Models of this computer had 8,000 and 13,000 vacuum tubes.
		Integral-1 105/	1957	N.A.	N.A.	Designed by A.A. Bednyakov of the Design Bureau of the former Ministry of Instrument Building and Means of Automation. This is a very large, general-purpose analog computer for solving both special and ordinary differential equations. One of these computers, which weigh 25 tons, is in use at Kiev University. It has 24 integrating linear modules.
		Electric Integrator 106/	1959	1	N.A.	Designed by I. Yulis of the Thermophysics Laboratory of Kazakh University. This is a new type of electric integrator for solving differential equations of problems relating to complex processes in gas dynamics and nuclear physics. It has been recommended for use in the radiotechnical industry and other branches of industry.
		EGDA-6/51 107/	1951	16	N.A.	Designed by the Institute of Mathematics of the Ukrainian Academy of Sciences in Kiev. This is an electric integrator for solving complex engineering problems. The first model of the EGDA was built in 1947 for modeling filtration problems for the Kiev Water Development Institute.
		EGDA-6/53 108/	1953	30	N.A.	The designer of this computer is unknown. This computer is in use in scientific research, pedagogical, and design institutes for modeling filtration problems.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Unknown	Analog (Continued)	EI-12 109/	Early 1950's	200 to 300	165,000	The designer of this computer is unknown. This is a general-purpose analog computer. This is an older machine for solving elliptical partial differential equations. The number of these computers in use depends on the manner in which the modules are combined.
	Digital	BESM-I 110/	1952	2 to 3	N.A.	Designed by S.A. Lebedev of the Institute of Precision Mechanics and Computation Technology of the Academy of Sciences, USSR. This is a large digital computer used for Sputnik calculations, for Chinese-Russian translation, for operational and technical planning, and for research in industry. It has a three-address, parallel, binary system with a floating decimal point and an average speed of 7,000 to 8,000 operations per second.
		BESM-II 111/	1959	3 to 6 as of the end of 1960	N.A.	Designed by S.A. Lebedev and Zak of the Institute of Precision Mechanics and Computation Technology of the Academy of Sciences, USSR. This is a large, binary, parallel, three-address, floating-decimal-point digital computer composed of several plug-in packages. It has an average speed of 8,000 to 10,000 operations per second. One of these computers is installed at the Computer Center of the Academy of Sciences, USSR, in Moscow. A good plant could produce 200 of these computers per year.
		M-1 112/	1952	1	N.A.	Designed by the Power Engineering Institute of the Academy of Sciences, USSR. This computer probably was the prototype for the M-2 (see p. 26, above). It is now used for training purposes only.
		M-3 113/	1956	N.A.	N.A.	Designed by I.S. Bruk of the Power Engineering Institute of the Academy of Sciences, USSR. This is a small, general-purpose digital computer designed for computer laboratories of scientific research institutes, training institutes, and design bureaus. This machine was constructed by the Scientific Research Institute of the Ministry of the Electrotechnical Industry and was released for serial production in 1958. Its capabilities, which are lower than those of the M-2 (see p. 26, above), include an average speed of 30 to 40 operations per second with a magnetic drum memory unit of 1,500 to 2,000 operations per second with a magnetic core memory unit. This computer is equipped with a communications link and is used for calculating electrotechnical devices. The comparable US type is the NCR-102d.

Plant Name and Location	Production: Type of Computer	Designation	Date Operational	Number Produced	Unit Price (1955 Rubles)	Remarks
Unknown	Digital (Continued)	M-10 114/	N.A.	1	N.A.	The designer of this computer is unknown. It has an average speed of 10,000 operations per second.
		M-50 115/	N.A.	Prototype	N.A.	Designed by the Yerevan Research Institute of Mathematical Machines. This computer, which is to have a speed of up to 50,000 operations per second, was in the final stages of design and development in June 1959.
		Setun 116/	1959	1	N.A.	Designed by N.P. Brunsentsev of Moscow University and by the Power Engineering Institute of the Academy of Sciences, USSR. This is an experimental, small, binary, serial, single-address, fixed-point digital computer that operates at an average speed of 4,000 to 5,000 operations per second. It is used in solving scientific problems in crystallography and nuclear energy.
		LEM-1 117/	1958	1	N.A.	Designed by the Electromodeling Laboratory of the All-Union Institute of Scientific and Technical Information. This is a small-scale, general-purpose digital computer that was under development in 1953. It is considered to be simple, reliable, and economical. It is designed for use in testing components and is rumored to be for use in air traffic control.
		Luch 118/	1958	1	N.A.	Designed by I.V. Lebedev of the Institute of Physics and Mathematics of the Belorussian Academy of Sciences. Research on this general-purpose computer began in 1956. It has an average speed of 4,000 operations per second. It also is known in Rumania as the Raza.
		Volga 119/	N.A.	1 to 3	N.A.	Designed by the Computer Laboratory of the Academy of Sciences, USSR. This is a small, general-purpose, transistorized digital computer that is one-tenth to one-eighth the size of the Strela (see p. 26, above). It was under development in 1957, and mass production began in 1958-59. It has an average speed of 2,000 operations per second.
		TsEM-1 120/	1953	1	N.A.	Designed by the All-Union Electrotechnical Institute and/or the Power Engineering Institute of the Academy of Sciences, USSR. This is a medium-size, two-address, 30-bit, fixed-point digital computer of the M-2 class (see p. 26, above). It is designed for solving mathematical problems at scientific research institutes and design bureaus.

Plant Name and Location	Type of Computer	Production: Designation	Production: Date Operational	Production: Number Produced	Production: Unit Price (1955 Rubles)	Remarks
Unknown	Digital (Continued)	High-speed computer 121/	N.A.	N.A.	N.A.	The designer of this machine is unknown. This is a partly transistorized digital computer capable of 100,000 operations per second. It was under construction in 1958. The comparable US type is the STRETCH computer.
		Omega 122/	1957-58	N.A.	N.A.	The designer probably was Y.V.Ya. Basilevskiy. This computer, which has an average operating speed of 6,000 operations per second, may be the same as the Volga.
		MARS-200 123/	N.A.	N.A.	N.A.	Designed by the Special Design and Technological Bureau for Biophysics Apparatus. This machine is designed for the automation of such industries as chemicals, petroleum refining, and power engineering. It is based on standard easily replaceable relay and electronic blocks. The number 200 refers to the number of control points. In the Moscow Rubber Plant, which is to install four of these machines, one of these computers regulates 48 processes simultaneously.
		MARS-300 124/	N.A.	1	N.A.	Designed by D.V. Ukladov, chief designer of the Special Design Bureau of the Moscow Tizpribor Plant. This computer is similar to the MARS-200 except that it has 300 control points. It was to be installed in the Yefremov Synthetic Rubber Plant.
		Auto driver 125/	1958	1	N.A.	The designer of this machine is unknown. This is a digital computer for the automatic regulation of the traction of a locomotive. It is organized like an analog computer, as all operations are executed in parallel. It has an average speed of 2,000 operations per second.
		EV-80-3 126/	1950	N.A.	350,000	The designer of this machine is unknown. This is a high-speed card programer for laboratory use that is comparable to the IBM-604 card punch and calculator. One of these machines was installed at the Laboratory of Machine and Computer Mathematics of the Kazakh Academy of Sciences in 1958. The computer was criticized for shortcomings caused by incomplete development of the technical design and by the poor quality of the individual units and parts.

APPENDIX B

SOVIET TERMINOLOGY FOR COMPUTERS

In the US the basic descriptive terminology for computers is more simplified than Soviet terminology, which uses several terms for the same meaning. Electronic computers are divided into two types: analog and digital. Computers are either general purpose or specialized.

The general class of electronic computers, including both analog and digital types, has been described in the USSR by the following terms:

Elektronnyye matematicheskiye mashiny -- electronic computers.

Matematicheskaya mashina -- an electronic computer.

Digital computers have been described in the following Soviet terms:

Universal'naya elektronnaya matematicheskaya mashina -- general-purpose electronic computer, digital.

Elektronnaya vychislitel'naya mashina -- electronic digital computer. Used to describe the Strela, the M-2, and the Ural.

Elektronnaya schetnaya mashina -- electronic digital computer. Used to describe the MESM and the BESM.

Schetno-reshayushchaya mashina -- digital computer.

Bystrodeystvuyushchaya elektronnaya matematicheskaya mashina -- high-speed digital computer.

Diskretnaya mashina -- digital (discrete) computer.

Mashina diskretnaya deystviya -- digital (discrete) computer.

Tsifrovaya mashina -- digital computer.

Universal'naya avtomaticheskaya tsifrovaya vychislitel'naya mashina -- general-purpose automatic digital computer.

Analog computers have been described by the following terms in the USSR:

Analogovaya matematicheskaya mashina -- analog computer.

Analogovaya matematicheskaya mashina obshchego primeneniya -- general-purpose analog computer.

Elektronnaya mashina nepereryvnaya deystviya -- analog computer (machine of continuous nature).

Elektricheskaya blochnaya nelineynaya modeliruyushchaya ustanovka -- analog computer composed of blocks or modular units.

Elektronnaya modeliruyushchaya ustanovka -- analog computer.

Spetsializirovannaya elektronnaya mashina -- special-purpose electronic computer. Used in discussing analog computers.

Other Soviet terms associated with computer production are the following:

Schetnaya mashina -- calculator.

Schetno-analiticheskaya mashina -- punch-card type of calculating and statistical machine.

Expansions of abbreviations for specific models of Soviet analog and digital computers are as follows:

BESM -- Bol'shaya (or bystrodeystvuyushchaya) elektronnaya schetnaya mashina -- large or high-speed digital electronic computer.

EMU -- Elektromodeliruyushchaya ustanovka -- elektromodeling apparatus, analog computer series.

MARS -- Mashina avtomaticheskogo regulirovaniya i signaliyatsii -- machine for automatic regulation and signaling.

MESM -- Malaya elektronnaya schetnaya mashina -- small digital computer.

MN -- Mashina nepereryvnogo -- analog (continuous action) computer.

TsEM -- Tsifrovaya elektronnaya mashina -- digital computer.

APPENDIX C

METHODOLOGY

I. Derivation of the Aggregate Index and Value Series

The index of growth and estimated value of Soviet production of all types of computing and mathematical machines (including electromechanical office machines) for 1950-65 is shown in Columns 1 and 2 of Table 2.* The index of growth for these years as shown in Column 1 was first constructed on the basis of official Soviet announcements. According to these announcements, if 100 is taken to represent the value of production in 1950, then the index of production of computing and mathematical machines was 737 in 1955, 127/ 1,470 in 1956, 128/ and 1,760 in 1957. 129/ The index of planned growth for the value of production of this category of equipment in 1965 compared with 1958 is 450. 130/ Intermediate years (1951-54 and 1959-64) were computed at the average annual rate of growth for the two plan periods. In order to link these two series, a rate of growth in 1958, compared with 1957, was required. This rate was estimated to have been approximately 24 percent, the implied average annual rate of growth necessary to meet the goals of the Seven Year Plan. The data in Column 2 of Table 2, representing the ruble value of production, was obtained by applying the 1958 value of production of 440 million rubles (derived from the announcements of Seven Year Plan goals 131/) to the index of production derived as above. Although this value series is based on a statement made in 1958, computer prices for planning purposes apparently had not, as late as 1960, undergone any significant change from 1955 prices. The value estimates are therefore presented in terms of 1955 rubles. The shift in cost structure brought on by changes in technology and learning curves and by economies of scale in this rapidly developing industry make the value comparisons over time, whether they be either in constant or in current prices, extremely difficult to interpret. This situation is equally true for the US. The real volume of production is believed to be most accurately portrayed by projecting the value in constant prices, and this practice was adopted for this report.

As an independent check on the announced value of production of this category of equipment, a calculation of the value of output in 1958 was obtained on the basis of the estimated labor force in the principal plants producing computing and mathematical machinery. The estimated average annual output per worker in 1958 for all sectors of the electronics industry (34,800 rubles) 132/ was applied to the number of workers engaged in production of computers and

* Table 2 follows on p. 44.

Table 2

Estimated Value of Production
of Computing and Mathematical Machines in the USSR a/
1950-65

	(1)	(2)	(3)
	Total Production of Computing and Mathematical Machines b/		Electronic Computers c/
Year	Index (1950 = 100)	Value d/ (Million 1955 Rubles)	Value d/ (Million 1955 Rubles)
1950	100	20	18
1951	150	30	27
1952	220	45	40
1953	330	67	60
1954	490	100	90
1955	740	150	130
1956	1,500	300	270
1957	1,800	360	320
1958	2,200	440	400
1959	2,700	550	490
1960	3,400	680	610
1961	4,200	840	760
1962	5,200	1,000	940
1963	6,400	1,300	1,200
1964	7,900	1,600	1,400
1965	9,800	2,000	1,800

a. After computation, data were rounded to two significant digits.
b. Including analog and digital computers with associated input, output, and storage equipment and electromechanical office machines.
c. This series includes value of input, output, and storage equipment associated with computers and was derived by deflating the total category series by the estimated value of electromechanical office machines produced.
d. Although the method of estimating this value series was based on a figure for a base year of 1958, it should be noted that computer pricing for plan purposes probably is still done in terms of 1955 rubles, which may be converted at the rate of 6 rubles to US $1.

calculators. The estimate of the labor force was based partly on reports of employment plus an estimate of the labor force engaged in production of computers in scientific research institutes and at newly organized plants.* These data indicate that production in 1958 equaled approximately 420 million rubles. Although the figure for the value of annual output per capita used in this calculation might not strictly apply to this sector of the industry, it is believed to be a valid first approximation. The estimated figure of 420 million rubles corresponds closely to that derived from official plan data (440 million rubles), and the official announcement has been accepted as one that accurately represents the value of production of this category of equipment in 1958.

II. Distribution of Product by Category

Column 3 of Table 2 shows the estimated value of production of electronic computers as a subcategory of the series for "computing and mathematical machines." The series for electronic computers alone was derived by deflating the series for the total category by the estimated value of production of electromechanical office machines. Table 3** provides a further division of the value of electronic computers between digital and analog types. Although a substantial amount of information was exploited in the derivation of Table 3, the primary objective was to provide an independent check on the data in Table 2, which were derived purely from official Soviet sources, rather than to estimate these subcategories with precision. The absence of some particularly important details, coupled with the ambiguity that surrounds the classification of products in this area of production generally, results in individual production series that are less reliable than the estimates of the aggregate value of production shown in Table 2. The results, however, are believed to be both useful and generally valid, as they provide indicators of the relative magnitude of production and changing patterns of growth of the two major categories of electronic computers and are essentially confirmed by alternative estimating methods.

A. Production of Electromechanical Office Machines

In some Soviet statements relating to the category of computing and mathematical machines it is clear that at least some types of standard electromechanical business calculators are included. Furthermore, information obtained from both the press and the East-West

* See Appendix A.

** Table 3 follows on p. 46.

Table 3

Estimated Value of Production
of Electronic Analog and Digital Computers in the USSR a/
1950-65

	Analog Computers		Digital Computers	
Year	Index (1950 = 100)	Value b/ (Million 1955 Rubles)	Index (1950 = 100)	Value b/ (Million 1955 Rubles)
1950	100	9	100	9
1951	180	16	120	11
1952	300	27	140	13
1953	470	42	200	18
1954	700	63	300	27
1955	1,000	90	490	44
1956	1,400	120	1,600	140
1957	1,800	160	1,800	160
1958	2,200	200	2,200	200
1959	2,700	240	2,800	250
1960	3,100	280	3,700	330
1961	3,500	320	4,900	440
1962	3,800	350	6,600	590
1963	4,100	370	8,800	790
1964	4,300	390	12,000	1,100
1965	4,400	400	15,000	1,400

a. After computation, data were rounded to two significant digits or less.
b. Although the method of estimating this value series was based on a figure for a base year of 1958, it should be noted that computer pricing for plan purposes probably is still done in terms of 1955 rubles, which may be converted at the rate of 6 rubles to US $1.

exchange program disclose that some of this type of equipment is manufactured in the same plants that produce electronic computers. Available details do not permit, however, more than a very rough estimate of the total value of such machines produced. An official of the Penza plant stated that in 1958 approximately 15 percent of the total production of that plant was devoted to this type of equipment. Similar information for other plants is not available. The value of production of calculators at the Penza plant represents only about 5 percent of the total production of computing and mathematical machines in the USSR (22 million rubles) in 1958 and may be taken as a

minimum estimate of such production. The upper limit of the range probably would not be more than the value of calculators that would be produced if all computer plants were devoting the same relative share of production to calculators as the Penza plant, or an upper limit of about 15 percent of the value of production of the entire category (66 million rubles). It is believed that both the upper and the lower limits are extreme cases and that the actual estimate will lie toward the midpoint of the range. Although this midpoint figure of 44 million rubles for 1958 production appears to be a very modest quantity for a nation of this size, the USSR is known to be a very heavy importer of calculators (in 1958, imports from East Germany alone totaled 30 million rubles). In the absence of further information the figure of 10 percent was accepted as a best estimate of production of office calculators, and the total series through 1965 was deflated by this amount to obtain the series for electronic computers alone. This constant deflator is believed to be most valid for the years 1958-60.

B. Distribution of Production of Electronic Computers Between Analog and Digital Types

The estimated product mix between analog and digital computers contained in Table 3 was derived by constructing an index of the growth of analog computers and by applying to this index the value of production of analog computers in 1958. The index was constructed from Soviet data which stated that production of analog computers in 1955 was 10 times that of 1950 133/ and that production is planned to double between 1958 and 1965. 134/ The rate of growth implied by these data is decreasing over time. It was assumed that this rate would decrease geometrically; therefore, to describe this growth function, the general formula $(1 + gd^n)^n(y_o) = y_n$ was used,

where: g = a constant rate of growth
d = decrease factor for the rate of growth over time (average annual)
y_o = output in the base year
y_n = output in the nth year, and n can take any value between 0 and 15 (y_o to y_{15})

The solution of this equation, given the two sets of data ($10y_o = y_5$ and $2y_8 = y_{15}$), yields values of d and g of 0.9313 and 0.835, respectively. When the function is plotted from y_o (1950) to y_{15} (1965), the index for analog computers shown in Table 3 is obtained.

The derived value of production of both digital and analog computers in the USSR in 1958 was 400 million rubles, as shown in Table 2. The product mix in 1958, according to Soviet statements, was approximately equally divided between digital and analog computers. 135/ The value of production of each type of computer in 1958 was therefore estimated at 200 million rubles. The value series contained in Table 3 was constructed from these data and from the indexes.

C. Cumulative Value of Electronic Computers Produced, 1950-58

Available data on the price and physical volume of production of electronic computers have been used to calculate estimates of the minimum cumulative value of analog and digital computers produced during 1950-58. The totals may then be compared with the cumulative value of computers that was derived by the method described in A, above.

1. Value of Digital Computers Produced, 1950-58

The total number of digital computers produced during this period varies slightly [redacted] but the majority of intelligence reports and estimates of other agencies indicate that this number is approximately 400. 136/ The majority of these computers are the small-size Ural-I, production of which by the end of 1958 has been reported to be not more than 300 units.* The unit price of this item is reported to be 1.1 million rubles, and 300 units would represent a total value of production of at least 330 million rubles. Reports of the number of Strela computers produced by the end of 1958 generally agree on a figure of about 15 units, at a reported price of about 6 million rubles per unit.** A total value for production of the Strela units, therefore, is approximately 90 million rubles. About two or three units of the BESM type of computer were constructed in the USSR before the end of 1958 and perhaps six or seven units of the M-20 computer had been produced, although these were not all in use by early 1959. The M-20 and BESM are large computers of the same general size as the Strela, although both the BESM and the M-20 are faster and more flexible machines. [redacted] this computer would be priced at perhaps three times as much as the Ural-II (for which the planned price of serially produced units was to be 1.5 million rubles) and estimated a price of 4 million to 5 million rubles each for serially produced units of the M-20. 137/ [redacted]

50X1
50X1
50X1
50X1
50X1

* See II, C, 2, p. 13, above.
** See Appendix A, p. 26, above.

A price of 10 million rubles was accepted as a reasonable estimate of the price of the BESM, as this machine is a contemporary of the Strela and is a much better machine. Production of BESM and M-20 computers would therefore represent a minimum total value of about 44 million rubles. In addition to the machines so far considered, a number of intermediate and small-size general-purpose and special-purpose digital machines (such as the M-2, the Kristall, the Pogoda, the Granit, the Setun, and the TsEM-1) have been produced in quantities of one to four each. The small-size M-3 was reported to be in serial production in 1958, but the quantity of output is not known. A conservative estimate of the total number of such units in use by the end of 1958, based on Soviet open sources [redacted] is approximately 70. No individual unit price is applicable for this category, but the capabilities of these machines compared with the Ural-I indicate that their range of value would vary from about one-half to perhaps one and one-half times the Ural-I price of 1.1 million rubles. In the absence of more specific details, an approximate average unit cost of 1 million rubles was assumed to be representative. This estimate yields a total value of about 70 million rubles. 50X1 50X1

It was therefore estimated that the minimum value of digital computers produced during 1950-58 was about 534 million rubles, or 15 percent less than the estimate of 622 million rubles derived from an analysis of the official Soviet growth statistics shown in Table 3. Because the former estimate was derived by a counting and costing procedure that involved the acceptance of minimum unit data and sometimes indirect price information, the value so derived would be expected to be inexact and somewhat less than the actual value of production. The relationship between the two figures is consistent with this expectation and generally enhances the confidence in the validity of the latter estimate.

2. Value of Electronic Analog Computers Produced, 1950-58

An exchange of computer specialists between the USSR and the US in early 1959 resulted in a statement by Soviet officials that between 4,000 and 5,000 electronic analog computers were then in use in the USSR. 139/ As there was no significant production before 1950 and as no important trade in analog computers has occurred, it is believed that this figure represents the approximate total of domestic production during 1950-58.

The large numbers of these machines that have been produced and the wide variation in types make it impracticable to estimate numbers and prices of individual machines to derive a cumulative total value as was done for the digital computers. An

alternative use of the above data was chosen to provide a method for checking the consistency of the derived series against available information on numbers and prices of machines produced. This procedure was as follows: (a) the total value of analog computers estimated to have been produced during 1950-58 (727 million rubles) was calculated from Table 3, and (b) on the basis of the Soviet statement that between 4,000 and 5,000 analog computers were in use in early 1959, an implied average price of between 145,000 and 180,000 rubles was derived. This price range can then be compared with the characteristics of Soviet machines and with US information on analog computers to determine whether or not it is consistent with information on Soviet and US practice.

Available information on prices of Soviet analog computers indicates a price range of from 30,000 rubles for very small nonlinear computers for solving equations of up to the 6th order to as much as 10 million rubles for a large unit for the study of complex problems of space and motion involving equations of up to the 40th order. The types that are known to have been in serial production, however, exhibit a narrower range of prices of from 30,000 to about 600,000 rubles. One of the earliest analog computers placed in production was the EI-12, with several hundred units produced at a price of 165,000 rubles. On the basis of quantity, the most important series of Soviet analog computers are the EMU types. This computer may be built up by combining standard modular units in a variety of ways to obtain a range of capabilities. EMU computers are priced between 30,000 and several million rubles, depending on the particular configuration used. Most machines in this series have been the small and medium-size models, with the average price falling in the range between 150,000 and 250,000 rubles.* Analog computers produced in series during 1950-58 for which prices are available include the IPT-4, 321,000 rubles; the IPT-5, 183,000 rubles; the MN-2, 54,000 rubles; the MPT-9, 569,000 rubles; and the MPT-11M, 530,000 rubles. The implied average price range of 145,000 to 180,000 rubles is consistent with the above unit prices of serially produced analog computers in the USSR.

Analogous data for US production of computers yield a similarly wide range of prices for individual scientific and industrial analog computers. Prices vary from a few thousand to several hundred thousand dollars. The average price of all such computers in the US was approximately $34,000 in 1958. 140/ Converting this figure to Soviet rubles at a rate of 6 rubles per dollar, estimated for the industrial electronic equipment sector of the Soviet electronics industry, yields a figure of 204,000 rubles, 141/ or slightly

* Calculated from data contained in Appendix A, p. 33, above.

more than the estimated range of 145,000 to 180,000 rubles for Soviet analog computers. US analog computers generally are slightly more expensive, for, according to available information, there are more high-precision analogs in serial production in the US than in the USSR.

Although the above procedure is an imprecise method of analyzing the aggregate value of an unknown product mix, available information does indicate that the pattern of Soviet production of analog computers is consistent with an average price of between 145,000 and 180,000 rubles. The fact that this price also exhibits a relatively consistent degree of comparability with US practice further supports the acceptance of the estimates derived in Tables 2 and 3.

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